CLASSIFICATION CHANGED ~~CONFIDENTIAL~~ UNCLASSIFIED

Copy No. 4

RM No. L7B27

To UNCLASSIFIED ~~MAY 7 1947~~

By authority of H. L. Dryden 6-5-53

per NACA Release form #1422. By HLR, 7-17-53.

CLASSIFICATION CHANGED TO RESTRICTED

NACA

RESEARCH MEMORANDUM

INITIAL TEST IN THE TRANSONIC RANGE OF FOUR FLUTTER AIRFOILS ATTACHED TO A FREELY FALLING BODY

By

J. G. Barmby and S. A. Clevenson

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

May 5, 1947

~~CONFIDENTIAL~~

UNCLASSIFIED

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

INITIAL TEST IN THE TRANSONIC RANGE OF FOUR FLUTTER AIRFOILS ATTACHED TO A FREELY FALLING BODY

By J. G. Barmby and S. A. Clevenson

SUMMARY

Results of the first test in the transonic range of four flutter airfoils attached to a freely falling body are reported.

Failures of the airfoils were telemetered and recorded. These airfoils were designed in an attempt to spread the range of flutter speeds. Telemeter records show that three of the airfoils failed at Mach numbers between 0.87 and 0.90 at an altitude of 14,000 feet, and the fourth airfoil apparently failed at a Mach number of 1.025 at 1900 feet above sea level.

The telemetered frequencies were obscured so that the airfoil failures cannot be attributed definitely to flutter. Better quantitative information can be expected from improved strain-telemeter equipment. It appears that the freely-falling-body technique offers promise for determining flutter characteristics in the transonic range.

INTRODUCTION

The investigation of flutter characteristics in the transonic range is of immediate importance in proposed aircraft designs. Theory in the transonic range is inadequate at the present time, and experiments in conventional wind tunnels in this range have severe limitations. It is therefore desirable to use other test methods for determining the flutter characteristics of airfoils at speeds near a Mach number of unity.

The method employed in the test described in this report is an adaptation of the freely-falling-body technique developed and used by the Langley Flight Research Division of the National Advisory Committee for Aeronautics for drag measurements. (See reference 1.) When applied to flutter tests, the method consists of attaching the subject airfoils to a bomb-shaped body and releasing the body from an airplane at high altitude. During the fall, the missile is tracked with phototheodolite and radar equipment while other desired measurements are telemetered to a ground receiving station. The development of the strain-gage telemeter equipment by the Langley Instrument Research Division was a necessary extension of this technique for flutter testing.

The purposes of this report were to describe the application of the freely-falling-body technique to transonic flutter tests and to give the results of the initial test.

SYMBOLS

r radius of body, 5.375 inches

c airfoil chord, inches

L airfoil length outboard of body, inches

d distance of dural insert behind leading edge, inches

c_i chord of dural insert, inches

t_i thickness of dural insert, inches

s number of chordwise slots in insert

e.a. distance of the elastic axis behind leading edge, percent chord

c.g. distance of center of gravity behind leading edge, percent chord

M Mach number

M_{cr} theoretical Mach number at which sonic velocity is first attained on the airfoil at zero lift (reference 2)

A.R. aspect ratio, $2 \frac{L + r}{c}$

b semichord in feet, $\frac{c}{2 \times 12}$, (reference 3)

a nondimensional elastic-axis position, $\frac{2 \times e.a.}{100} - 1$ (reference 3)

$a + x_{\alpha}$ nondimensional center-of-gravity position, $\frac{2 \times c.g.}{100} - 1$ (reference 3)

κ weight ratio, $\frac{\pi \rho b^2}{M}$, where M is mass of airfoil per unit length (reference 3)

${r_{\alpha}}^2$ square of nondimensional radius of gyration about elastic axis, $\frac{I_{\alpha}}{Mb^2}$, where I_{α} is polar moment of inertia about elastic axis (reference 3)

f_{h_1} first bending frequency, cycles per second

f_{h_2} second bending frequency, cycles per second

f_{α} first torsion frequency, cycles per second

t time after release of missile from airplane, seconds

h geometric altitude, feet

p_s static pressure, pounds per square foot

T free-air temperature, $^{\circ}F$ absolute

T.A.S. true air velocity, miles per hour

ρ air density, $\left(0.00238 \left(\frac{p_s}{2110}\right)\left(\frac{519}{T}\right)\right)$, pound × second squared × feet^{-4}

q dynamic pressure $\left(\frac{1}{2}\rho(v)^2\right)$, pounds per square foot

v true air velocity, feet per second

V_F calculated flutter speed in miles per hour; ~~two-dimensional~~ incompressible theory employing first bending mode and density at time of failure (reference 3)

V_D calculated divergence speed in miles per hour; two-dimensional incompressible theory employing first bending mode and density at time of failure (reference 3)

$\frac{v}{b\omega_\alpha}$ nondimensional flutter speed coefficient (reference 3)

APPARATUS AND METHODS

Model

A photograph and dimensional drawing of the complete model are shown in figures 1 and 2. It was decided to use four wings of different aspect ratio and properties attached to the same body in order to cover a range of conditions in the first application of the freely-falling-body technique to flutter tests. Interaction of the airfoils was minimized by the high rigidity and large mass of the body. This 1300-pound missile was also designed for large stability to minimize the effect of an airfoil failure on the remaining wings.

Figure 3 shows geometric properties of the airfoils. In table I are listed the airfoil flutter parameters. The section critical speed and coordinates were obtained from reference 2.

Instrumentation

Each of the four airfoils was equipped with a "break wire" and four strain gages. The gages were mounted near the root of each airfoil to record either bending or torsional strains. Failure of the wing was recorded by the breaking of a break wire. Another break wire was attached to the missile and to the airplane carrying it so that the time of release was recorded. A longitudinal accelerometer was mounted in the missile. Signals from the accelerometer, gages and break wires were combined and transmitted over four telemeter channels to two receiving stations. The data were recorded by an 8-channel Miller oscillograph recorder at one station and by duplicate 14-channel Consolidated oscillograph recorders at the other. Radar and phototheodolite were also used.

Measurements

Zero air-speed flutter parameters were measured by ground tests. The telemetered signals were recorded at both receiving stations during the entire descent of the missile.

Free-air temperature and static pressure were measured as a function of geometric altitude by synchronizing thermometer, pressure-altimeter, radar, and phototheodolite readings during the descent of the airplane which carried the missile.

Reduction of Data

Knowing the initial airplane ground speed from radar data and using time after release as the primary variable, the telemetered longitudinal acceleration curve was integrated to give the missile velocity. Integration of the vertical component of the missile velocity gave the geometric altitude of the missile. Once the path had been determined, the free-air temperature and static pressure were read from the air data obtained during the descent of the airplane to obtain the time history of the fall.

The time of failure of each wing was read from the break-wire telemeter record, and the associated conditions were determined from the time-history curves. The Mach number was obtained from the velocity and temperature. By employing the general gas law the density was calculated from the temperature and pressure points.

RESULTS AND DISCUSSION

The time history of the fall is shown in figure 4. Here the time variation of the missile altitude and velocity are plotted together with the free-air static pressure and temperature that correspond to the missile geometric altitude. The radar release altitude checks within 5 feet the altitude obtained from the longitudinal accelerometer by integration of the vertical acceleration component to get vertical displacement.

Final results are listed in table II. The opening of the break-wire channel was considered failure of the wing.

Figure 5 shows a sample oscillograph record from the Miller recorder. There is noted from the strain-gage channel a frequency of 3.1 cycles per second, probably due to a short period oscillation of the missile. The break-wire failures are indicated by abrupt displacements of the oscillograph curves. It is seen that wings I, II, and III broke off within 2 seconds of each other. From the high-speed Consolidated records, it was seen that wings I, II, and III show a definite change in the characteristics of the strain-gage channels coincident with the break-wire failure, while the strain-gage channel of wing IV opened 2.0 seconds ahead of break-wire failure.

The strain-gage records before the breaks were not sufficiently distinct to determine frequencies in the order of magnitude expected for flutter frequencies. For that reason improvements of the strain-gage telemeter circuit were considered advisable and are being made before further freely-falling-body flutter tests are carried out.

Flutter calculations were made using the two-dimensional incompressible theory of reference 3. In figure 6 the variations in the calculated flutter coefficients with frequency ratio for the four airfoils are shown. This figure was plotted from the calculations using the densities at the altitudes of failure.

Also shown in figure 6 are the bending frequency spectrums. The ratios of the first and second bending frequencies to the torsion frequencies are indicated above the abscissa scale.

For purposes of preliminary comparison the theoretical flutter speeds and the experimental results are shown in figure 7. Using the theory of reference 3, two-dimensional, incompressible flutter speeds corresponding to first mode flutter at various altitudes were superimposed on the missile flight path. No aspect ratio or compressibility corrections were employed in this preliminary calculation. The airfoil failure points and critical Mach number are also indicated on this curve.

CONCLUDING REMARKS

All the airfoils apparently failed at supercritical Mach numbers.

The telemetered frequencies were obscured so that the airfoil failures cannot be attributed definitely to flutter. Better quantitative flutter characteristics can be expected with more refined instrumentation.

The freely-falling-body method with an improved telemeter appears to offer promise for flutter tests in the transonic range.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va.

REFERENCES

1. Mathews, Charles W., and Thompson, Jim Rogers: Comparative Drag Measurements at Transonic Speeds of Rectangular and Swept-Back NACA 65_1-009 Airfoils Mounted on a Freely Falling Body. NACA ACR No. L5G30, 1945.

2. Abbott, Ira H., von Doenhoff, Albert E., and Stivers, Louis S., Jr.: Summary of Airfoil Data. NACA ACR No. L5C05, 1945.

3. Theodorsen, Theodore, and Garrick, I. E.: Mechanism of Flutter - A Theoretical and Experimental Investigation of the Flutter Problem. NACA Rep. No. 685, 1940.

[redacted]

TABLE I

AIRFOIL PARAMETERS

Parameter	Airfoil number			
	I	II	III	IV
Section	65009	65009	65009	65009
M_{cr}	0.79	0.79	0.79	0.79
c	8	8	8	8
L	28	22.25	22	16
A.R.	8.34	6.92	6.86	5.34
b	1/3	1/3	1/3	1/3
a	−0.26	−0.25	−0.24	−0.24
$a + x_\alpha$	−0.08	−0.10	−0.10	−0.08
$1/\kappa$ (standard conditions)	62	58	64	60
${r_\alpha}^2$	0.18	0.20	0.17	0.18
f_{h_1}	10	17	17	29
f_{h_2}	61	108	103	194
f_α	87	83	117	161

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE II

RESULTS OF DROP

INFORMATION AT TIME OF WING FAILURE

Parameter	Airfoil number			
	I	II	III	IV
M	0.867	0.882	0.895	1.025
T.A.S.	640	653	663	792
ρ	0.00145	0.00149	0.00152	0.00217
q	636	680	718	1466
$1/k$	102.0	92.8	100.4	65.8
t	26.53	27.43	28.11	40.24
h	15,400	14,600	14,000	1,900
T	488	491	492	536
p_s	1210	1250	1275	1985
V_F	562	546	750	843
V_D	768	722	959	1100

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

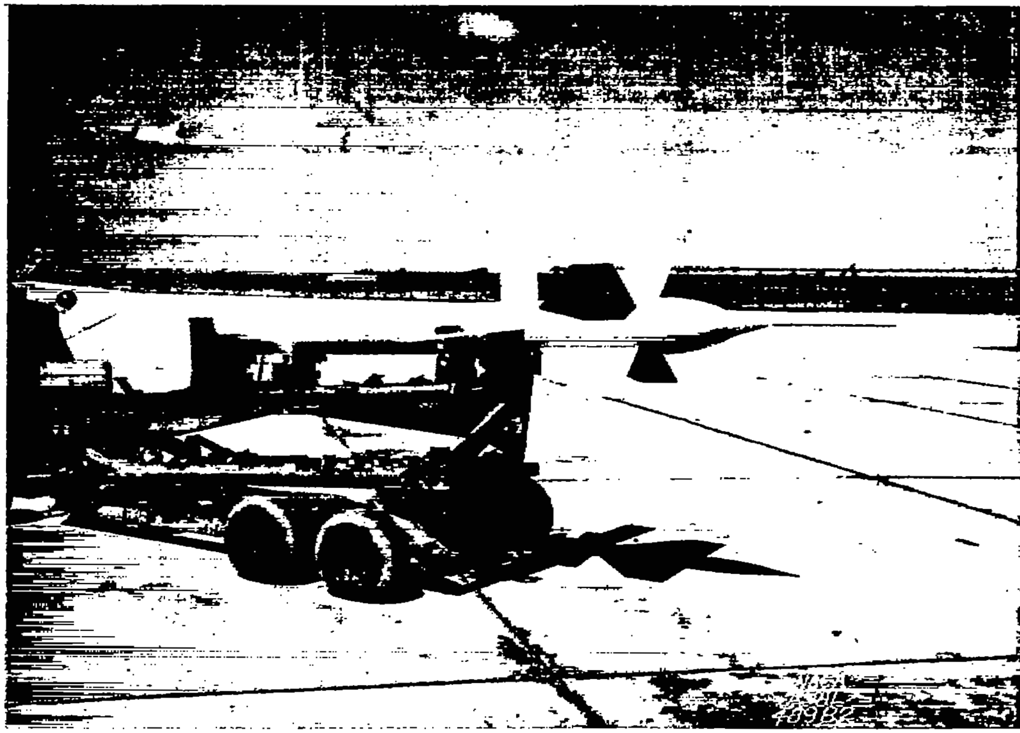
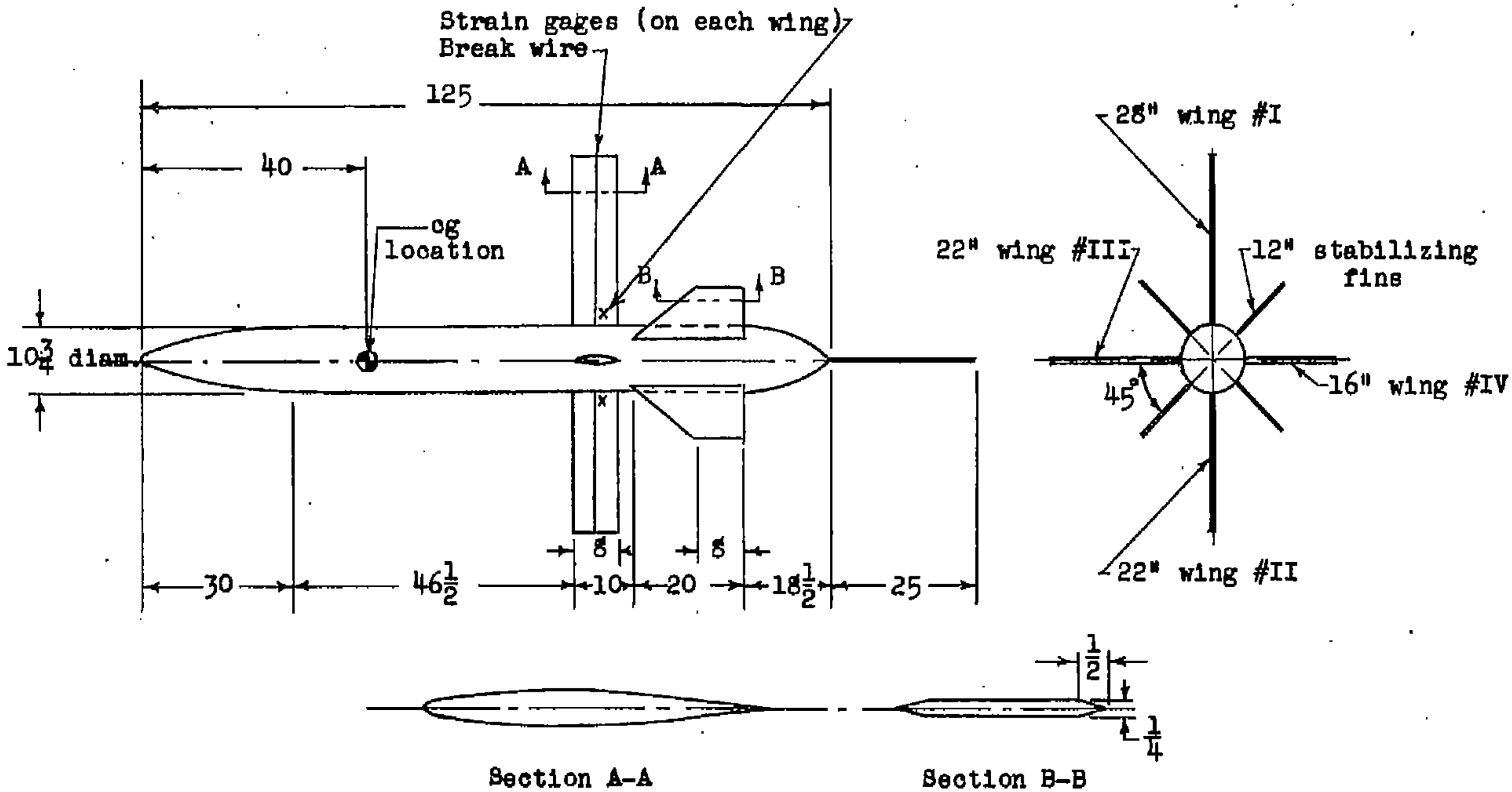


Figure 1.- Flutter missile number 1.

[redacted]

[redacted]

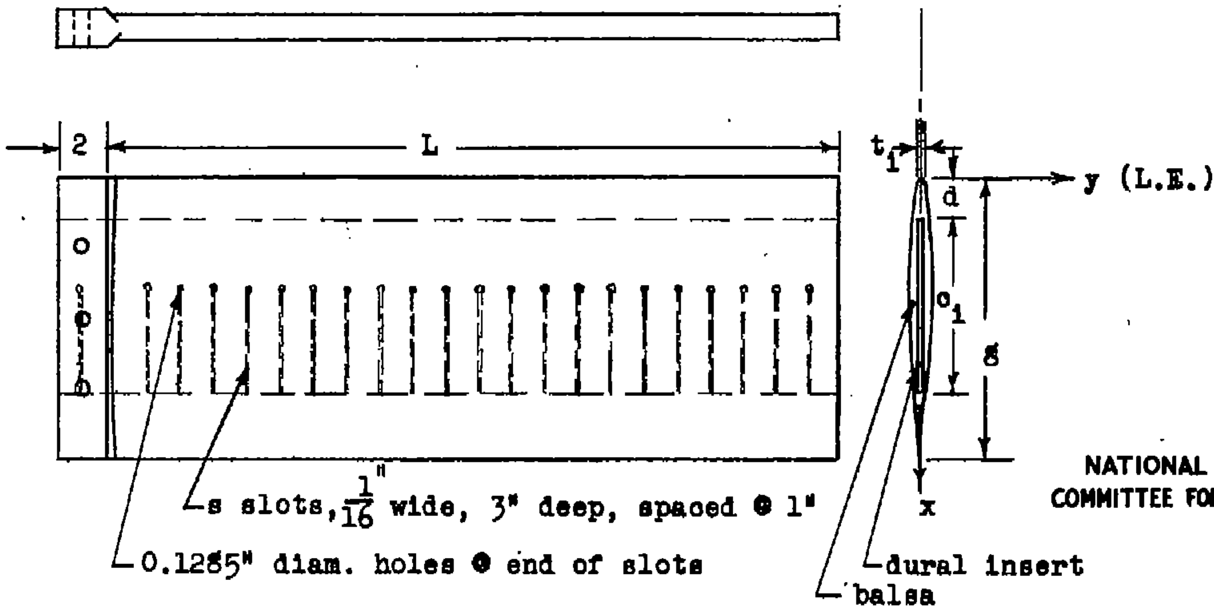


NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

[redacted]

Figure 2.-Dimensional drawing of flutter missile number 1.

[redacted]



NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

Parameter	Wing Number I	II	III	IV
c (in.)	8	8	8	8
l (in.)	28	22¼	22	16
d (in.)	1⅛	5/8	1⅛	1⅛
c_1 (in.)	5	5⅞	5	5
t_1 (in.)	.25	.19	.25	.25
s	29	23	23	17
ea %c	37	37.5	37	37
cg %c	46	45	45	46

[redacted]

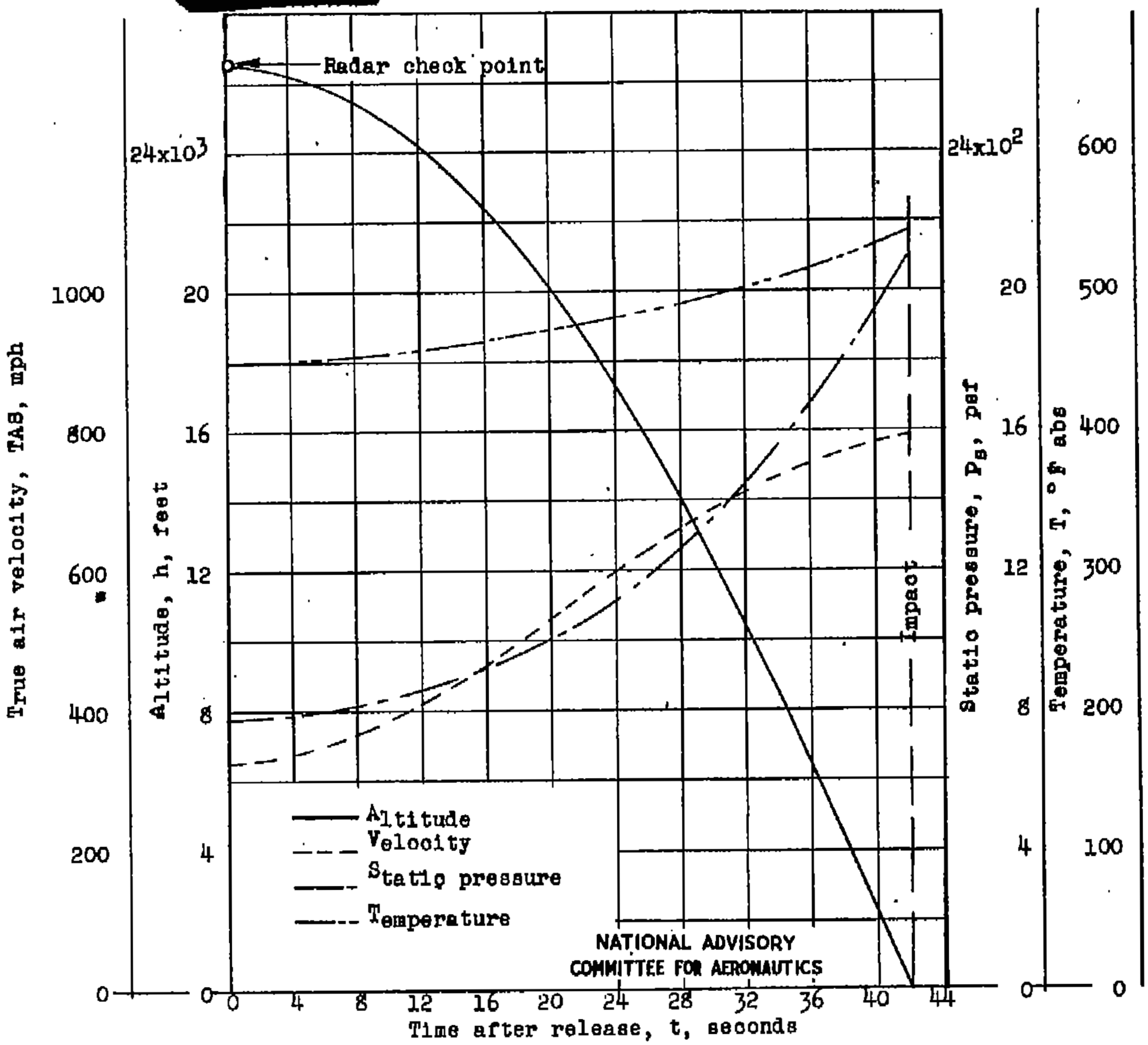
65009 section

x	$y_u = y_l$	x	$y_u = y_l$
0	0	2.40	0.342
0.10	0.085	3.20	0.360
0.20	0.114	4.00	0.346
0.40	0.157	4.80	0.300
0.60	0.191	5.60	0.228
0.80	0.219	6.40	0.144
1.20	0.264	7.20	0.059
1.60	0.298	7.60	0.022
		8.00	0.0

L.E. rad. = 0.044

Figure 3.- Geometric properties of airfoil.

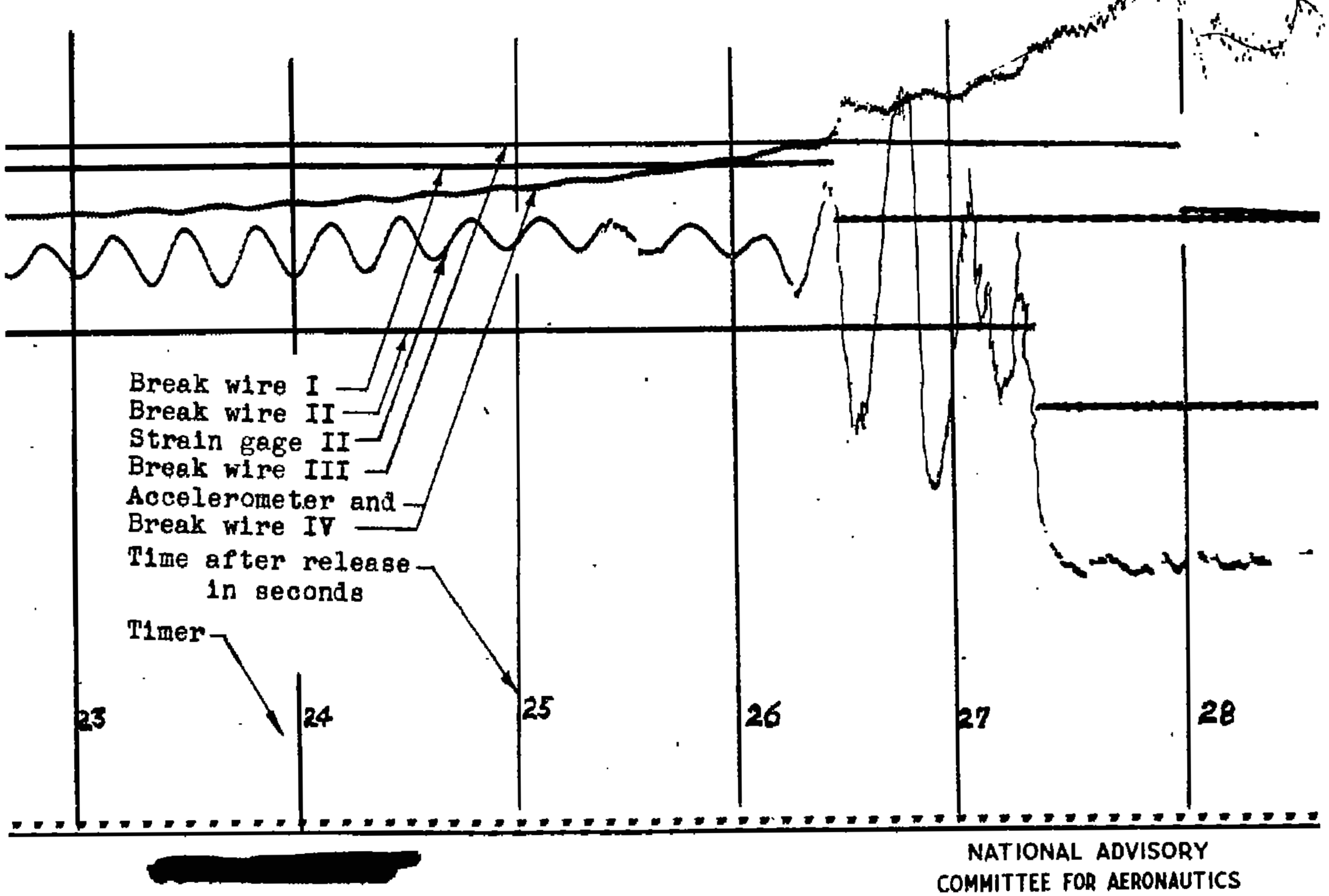
[redacted]



[redacted]

Figure 4.-Time history of fall.

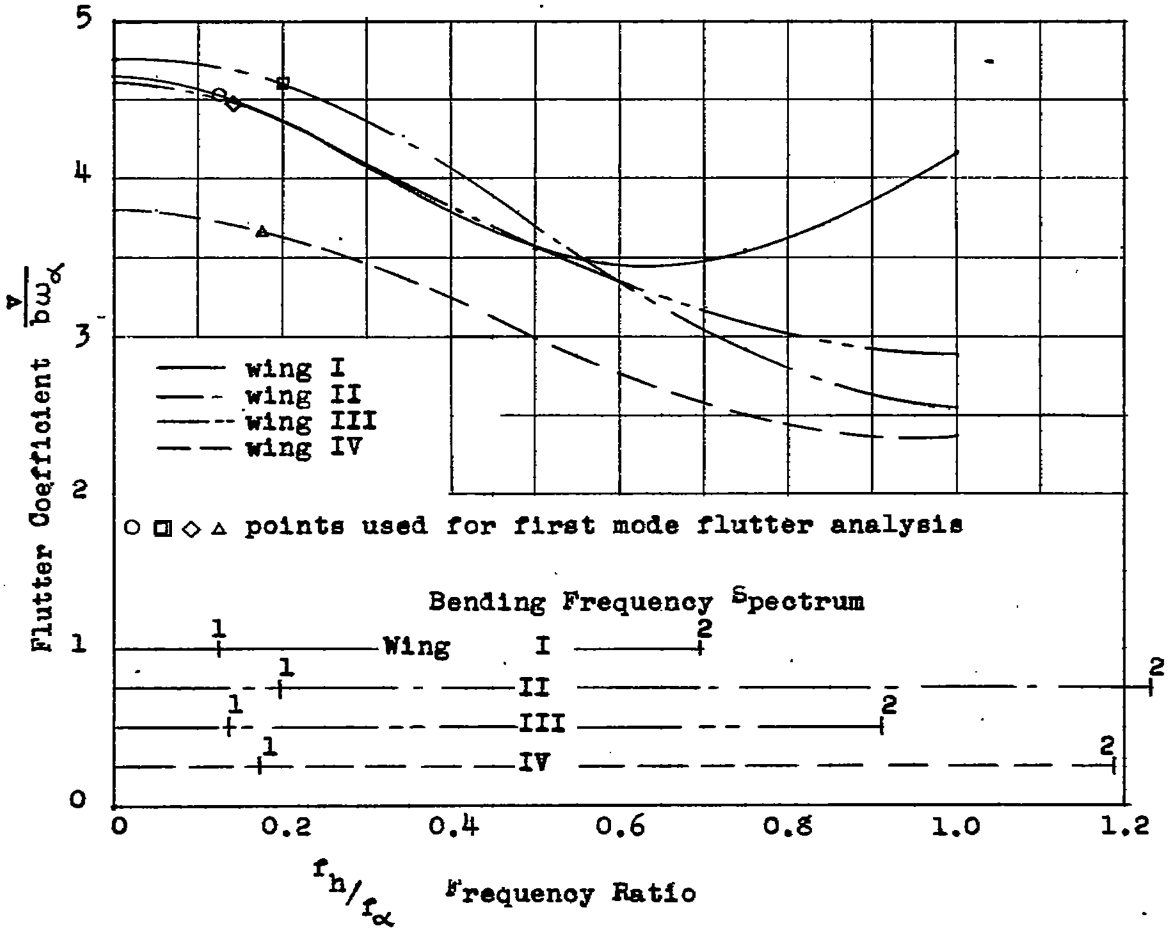
[redacted]



[redacted]

Figure 5.- Sample oscillograph record showing the variation with time of four break-wire channels and one strain-gage channel.

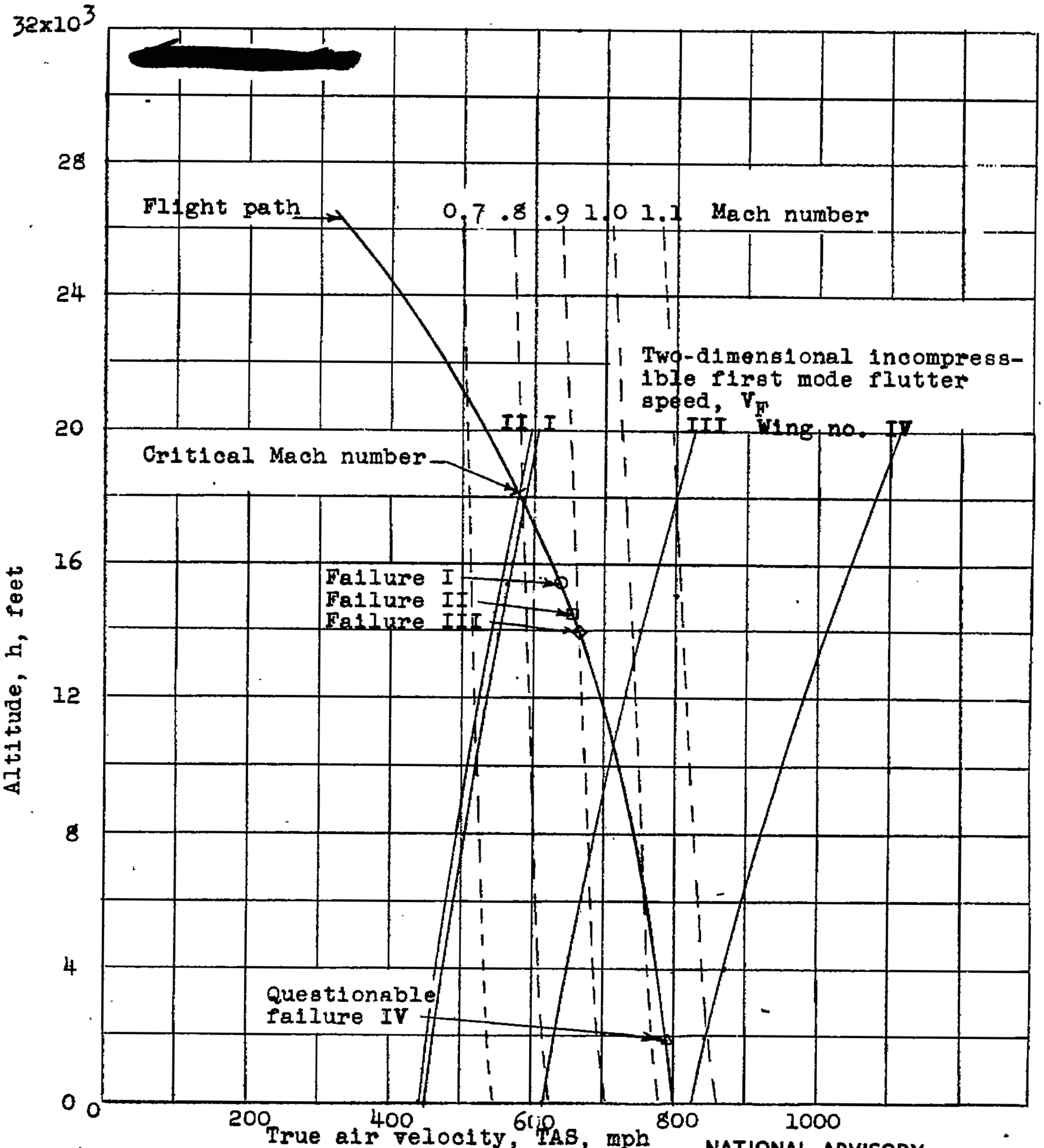
[redacted]



[redacted]

Figure 7.- Theoretical flutter calculations superimposed on experimental results to show velocity variation with altitude.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS



[redacted]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Figure 7.- Theoretical flutter calculations superimposed on experimental results to show velocity variation with altitude.